United States
Department of
Agriculture

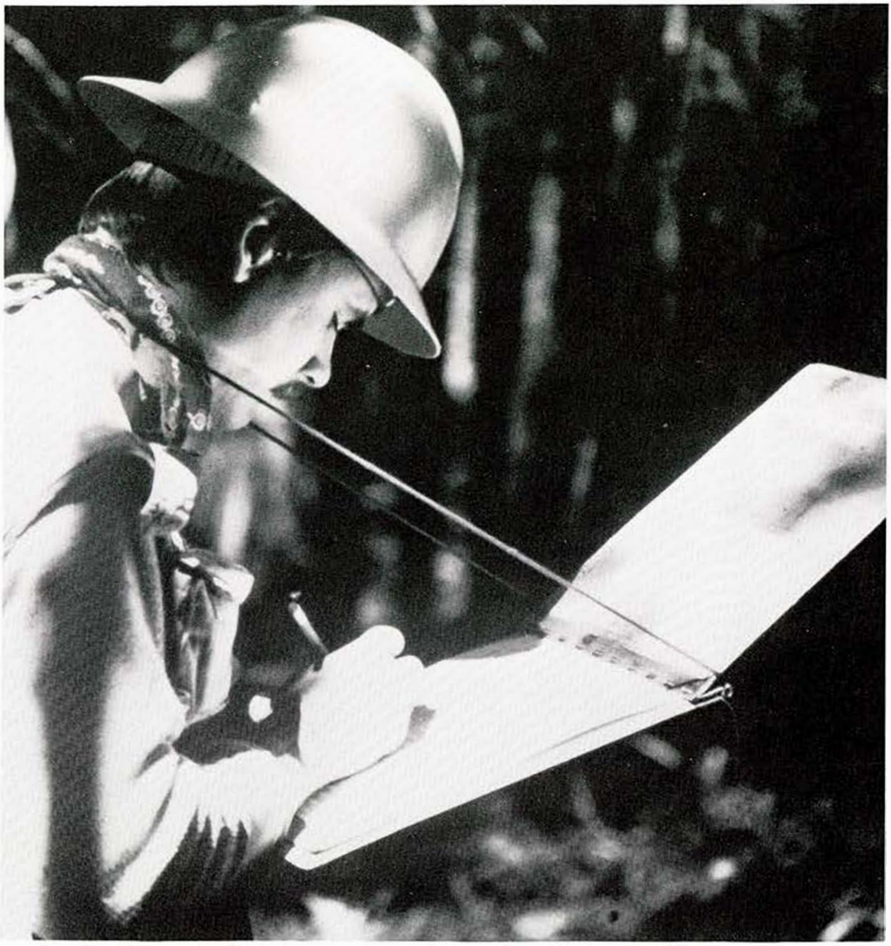
Forest Service

Cooperative
State Research
Service

Agriculture
Handbook
No. 636

Spruce
Budworms
Handbook

Rating Spruce–Fir Stands for Spruce Budworm Damage in Eastern North America



In 1977, the United States Department of Agriculture and the Canada Department of the Environment agreed to cooperate in an expanded and accelerated research and development effort, the Canada/United States Spruce Budworms Program (CANUSA), aimed at the spruce budworm in the East and the western spruce budworm in the West. The objective of CANUSA was to design and evaluate strategies for controlling the spruce budworms and managing budworm-susceptible forests, to help forest managers attain their objectives in an economically and environmentally accepted manner. The work reported in this handbook was wholly or partially funded by the CANUSA Program. This manual is one in a series on the spruce budworm.

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Spruce Budworms
Program

February 1985

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Rating Spruce–Fir Stands for Spruce Budworm Damage in Eastern North America

by John A. Witter and Ann M. Lynch[1]

Introduction

Numerous studies in Eastern North America during the last 40 years have recorded the amount of tree mortality in individual spruce–fir stands during outbreaks of the spruce budworm (Witter et al. 1984). Mortality in mature balsam fir stands often ranges from 70 to 100 percent; in immature stands, mortality often ranges from 30 to 70 percent (MacLean 1980). However, mortality in an individual stand can be less. High mortality is more likely in stands with the following characteristics:

1. Fifty percent or more of the stand composed of balsam fir, white spruce, and/or red spruce.
2. Mature fir stands, 50 or more years old.
3. High basal area of balsam fir, white spruce, and/or red spruce.
4. Open stands in which spiked tops of host species protrude above the forest canopy.
5. Stands on poorly drained soils that are abnormally dry or wet.
6. Extensive stands of mature spruce–fir type.
7. Stands located downwind of the current outbreak.
8. Stands growing at elevations lower than 2,300 ft (701 m) and south of 50° latitude (a line extending from the north shore of the Gulf of St. Lawrence to Winnipeg, MB).

A number of rating systems have been developed to assist land managers in predicting the vulnerability of spruce–fir stands to the spruce budworm. This handbook describes the objectives and uses of rating systems in spruce–fir management and the most recently developed rating systems.

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Terminology, Objectives, and Uses

Several terms are often used when discussing rating systems that predict the amount of damage to spruce–fir stands from spruce budworm feeding. One term is vulnerability, which is the probability of tree mortality in a stand once budworm attack occurs. A hazard-rating system is a procedure for assessing this vulnerability.

Rating systems for the spruce budworm are designed to provide information for either short- or long-term management decisions. Short-term rating systems help managers decide which stands to spray or salvage during the next several years.

Long-term rating systems help the land manager plan actions for reducing the vulnerability of the forest over time. Stand vulnerability is influenced by stand and site characteristics such as the proportion of host species, species composition, density, stocking, maturity, structure, vigor, topography, and drainage. These associations vary considerably between regions (MacLean 1980, Lynch et al. 1984c). Therefore, region-specific hazard-rating systems have been developed. Differences in forest-management objectives, management intensity, and inventory systems have also been built into the region-specific systems. Long-term rating systems can be used to help select cutting areas and to schedule presalvage and salvage harvesting programs. Implementation of these rating systems by the land manager is relatively easy because the necessary data are readily available from routine compartment examinations and inventory systems.

This handbook describes five currently available rating systems. They are designed for planning protective spraying and salvage operations or for long-term planning.

Systems for Planning Protective Spraying and Salvage Operations

Hazard-rating systems to help plan spray and salvage operations are based primarily on ground or aerial sampling.

Ground-Based Sampling—This type of system has been used for more than 25 years by land managers planning protective spray programs or salvage operations for the next year. Pest managers often want to limit spray or salvage operations to stands with the greatest potential for damage (e.g., high hazard) and with the highest economic value. Rating systems based on ground sampling incorporate short-term, year-to-year procedures that identify high-hazard areas. All short-term rating systems for Eastern North America that use ground sampling are similar (Dorais and Kettela 1982). However, the measurement techniques and values used in the individual systems often differ.

The following procedure is based on the approach used in Maine in 1982 (Trial and Devine 1983):

1. In July and August, conduct aerial surveys over the entire spruce–fir type in the State or Province.
2. Map the amount of defoliation for the entire area.
3. During August and September, conduct egg-mass surveys or overwintering second-instar larval counts at numerous sampling locations. (Over 1,000 sampling locations were used in Maine.)
4. Determine the number of new egg masses or second-instar budworm larvae per 100 ft^2 (9.3 m^2) of foliage by sampling one branch from each of three dominant or codominant fir trees at each location.
5. Determine the current and previous defoliation (the two previous years' needles) and tree vigor by examining the foliage from one branch from each of three dominant or codominant fir trees at each location.
6. During early fall, determine a hazard-rating value (table 1) for each stand or location by assigning values to parameters such as current and previous defoliation, tree vigor, and the density of egg masses or second-instar larvae. The value for the stand is determined by summing the values for each parameter.

7. During early fall, use the egg-mass or second-instar larval samples to prepare a budworm population prediction map for the State or Province.

8. Use the individual hazard values for each stand to prepare a composite hazard map for the State or Province.

9. In late fall, use the composite hazard map along with management plans and data on economic, environmental, social, and political conditions to select the spray areas or salvage areas for the next year.

Aerial Sampling System—McCarthy et al. (1983) combined photointerpretations of stand defoliation, mortality, density, and proportion in host species into a simple, efficient system for rating damage. The procedure indexes stands in terms of relative damage probabilities. The index values can be used by land managers to plan which stands need to be salvaged or protected during the next 1 to 3 years.

Color photographs (35- or 70-mm) are taken with stereo overlap from fixed-wing, light aircraft. Use table 2 in interpreting the photographs and determining the stand hazard-rating value. The general procedure is to

1. Rank crown defoliation of each host tree as:

1 = 0 to 20 percent.
2 = 21 to 50 percent.
3 = 51 percent or more without topkill.
4 = 51 percent or more with topkill.

Then compute the average tree defoliation rank and assign a class rank.

2. Determine percent mortality of host species and assign a class rank.

3. Categorize stand density as open, average, or dense; determine the proportion of trees that are in host species; assign a class rank.

4. Compute the stand hazard-rating value by adding the values for steps 1, 2, and 3. Categorize the values as low, moderate, high, or severe.

Table 1—Hazard-rating system used in Maine during 1982 (modified from Trial and Devine 1983)

Current defoliation (%)		**Value**	**Previous defoliation(%)**[1]		**Value**[2]
Trace	0–5	0	Trace	0–9	0
Light	6–20	1	Light	10–49	3
Moderate	21–50	2	Moderate	50–129	6
Heavy	51–80	4	Severe	130 +	9
Severe	81 +	6			

Egg-mass or overwintering larval deposit (number)			
Category	*Egg masses*[3]	*Second-instar larvae*[4]	*Value*
Light	0–99	0–175	1
Moderate	100–239	176–500	2
High	240–399	501–1099	3
Very high	400–999	1100 +	5
Extreme	1000 +	1100 +	5

		Total hazard rating	
Tree vigor	**Value**	*Category*	*Hazard value*
Good (current foliage healthy)	0	Low	0–6
Fair (shoot production moderate)	1	Moderate	7–15
Poor (some growth capacity)	2	High	16–22
Very poor (nil)	3	Severe	23–26

[1]The 2 previous years' needles.
[2]Add three points if there are trees with dead tops in the area (10 to 20 percent of the trees).
[3]Number of budworm egg masses/100 ft^2 (9.3 m^2) of foliage.
[4]Number of second-instar budworm larvae/100 ft^2 of foliage.

This rating procedure provides an index that ranks stands by the relative probability of their being damaged in the near future. The variables and values in table 2 can be modified to meet equipment limitations and local forest-management conditions. An instruction manual (Olson et al. 1982) and pest management leaflet (Olson et al. 1984) are available to assist land managers in the technical aspects of this procedure.

Systems for Long-Term Planning

Separate long-term rating systems have been developed for Minnesota, Michigan, and eastern Canada. The systems used in Minnesota and Michigan are based on quantitative empirical models that provide estimates of potential loss of basal area. These estimates can be used to rank stands when setting harvest or treatment priorities. The system used in eastern Canada is a qualitative mechanistic system that indexes vulnerability. The index formula was selected after extensive testing of many alternative forms. Each of these systems is designed to use available inventory data and to assist forest managers in planning stand management and harvest operations over long time periods. Each is suited to the particular forest management and inventory system for which it was developed.

Minnesota Rating System—The Minnesota system is based on the following multiple linear regression model developed by Batzer and Hastings (1981):

$$DBA = -4.1 + 0.97\ BA.BF - 0.42\ BA\%NH$$

where

DBA = dead balsam fir basal area (ft^2/acre),

BA.BF = preoutbreak balsam fir basal area (ft^2/acre),

BA%NH = percent stand basal area in nonhost species,

$R^2 = 0.87$, SEE = 12.5 ft^2/acre, and n = 35.

Table 2—Stand hazard-rating values obtained from 35-mm photographs and used to predict amount potential damage (modified from Olson et al. 1982, McCarthy et al. 1983)

Average stand defoliation rank	Class label	Class value
0.0–1.2	Trace	0
1.3–1.9	Light	1
2.0–2.9	Moderate	2
3.0–4.0	Heavy	3

Stand mortality(%)		Value
Low	0–9	0
Medium	10–29	2
High	30–49	4
Severe	≥50	6

Proportion of stand in host species

Proportion of host species	*Stand density value* Open	Average	Dense
< 30	1	1	2
30 to 60	2	2	4
> 60	3	4	6

Stand hazard-rating value

Category	*Hazard value*
Low	0–4
Moderate	5–8
High	9–10
Severe	11–15

The model estimates potential balsam fir basal area loss in trees 4 inches (10 cm) or larger in diameter at breast height (d.b.h.) as a function of the initial balsam fir basal area and percent nonhost basal area. Estimates of potential loss can be made during routine compartment or inventory examinations. To estimate the potential for dead balsam fir from spruce budworm attack:

1. Determine basal area per acre of balsam fir in the stand.

2. Determine the percentage of stand basal area that is made up of species other than balsam fir or spruce.

3. Find the potential for dead balsam fir basal area (ft^2/acre) where these values intersect in the following tabulation (Batzer and Hastings 1980, 1981):

Stand basal area in nonhost species (%)	*Preoutbreak balsam fir basal area (ft^2/acre)* 20	40	60	80	100	120
0	15	35	54	73	93	112
10	11	30	50	69	89	108
20	7	26	46	65	84	104
30	3	22	41	61	80	100
40		18	37	57	76	95
50		14	33	52	72	91
60		9	29	48	68	87

Stands in which the potential loss exceeds acceptable limits should be harvested first. The land manager must determine the acceptable limits on potential loss based on current economic conditions.

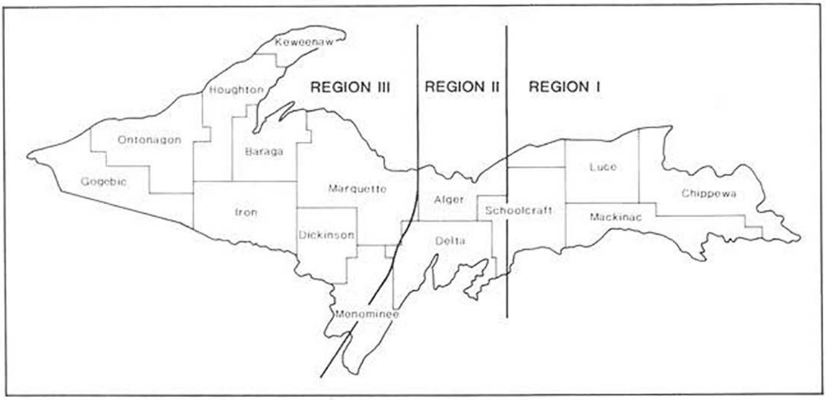

Figure 1—The Upper Peninsula of Michigan, showing county boundaries and the three regions used as strata.

Rating System for Michigan's Upper Peninsula—Lynch et al. (1984a, b) developed a system that rates hazards separately for each of three geographic regions that make up Michigan's Upper Peninsula (fig. 1). These geographic strata reflect differences in topography, climate, forest structure, management intensity, and timing of the current spruce budworm outbreak. The system is not applicable to stands on wetland sites with organic soils. Potential losses to balsam fir in the eastern area (Region I) increase with higher initial fir basal area and decrease with increasing percent stand basal area in aspen (*Populus* spp.). Potential losses in the central area (Region II) are uniformly low. Potential losses in balsam fir in the western area (Region III) increase as the initial fir basal area increases, increase as percent stand component (stem count) in fir decreases, and are higher toward the West. The following are the linear models (Lynch et al. 1984a) used to estimate potential impact in Michigan, by region.

Region I:

$$\mathrm{DBA} = 0.51 + 0.90\ \mathrm{BA.BF} - 0.26\ \mathrm{BA\%AP}$$

where

DBA = dead balsam fir basal area (ft^2/acre),

BA.BF = preoutbreak balsam fir basal area (ft^2/acre),

BA%AP = percent stand basal area in aspen, and

$R^2 = 0.90$, SEE = 7.6 ft^2/acre, and n = 24.

Region II:

$DBA = 4 \pm 5$ ft^2/acre.

Region III:

Stands with less than 44 ft^2/acre of balsam fir basal area.

$DBA = 6 \pm 7$ ft^2/acre.

Stands with more than 44 ft^2/acre of balsam fir basal area.

$$DBA = 1.46 + 0.36\ BA.BF - 0.79\ NT\%BF + 1.14\ Range$$

where

BA.BF = preoutbreak balsam fir basal area (ft^2/acre).

NT%BF = percent number of trees that are fir.

Range = stand position on an east–west gradient (value used is the U.S. public-land survey range, of Township–Range–Section number).

$R^2 = 0.58$, SEE = 7.0 ft^2/acre, and n = 41.

To rank hazard for a stand in Region I,

1. Determine the basal area per acre in balsam fir (trees 4.6 inches [11.7 cm] or larger in d.b.h.) in the stand.
2. Determine the percentage of trees 4.6 inches or larger in d.b.h. that are aspen.
3. Find the potential for dead fir basal area where these values intersect in table 3.
4. Identify the hazard (high, moderate, or low) by the shading in table 3.

The hazard for a stand in Region II is low, with an estimated 4 ± 5 ft^2/acre of potential dead balsam fir basal area.

To rank hazard for a stand in Region III,

1. Determine the basal area per acre of balsam fir in the stand:
   - If this value is 44 ft^2/acre or less, hazard is low, 6 ± 7 ft^2/acre of potential dead balsam fir basal area;
   - If this value is greater than 44 ft^2/ acre, proceed with step 2.

2. Determine the percentage of trees in the stand that are fir.
3. Determine the east–west position of the stand according to the U.S. public-land survey Township–Range–Section.
4. Find the potential for dead fir basal area where these values intersect in table 3.
5. Identify the hazard (high, moderate, or low) by the shading in table 3.

Priorities for stand harvests or treatments can be determined according to the hazard ranks or to comparative estimates of potential impact.

Canadian Rating Systems—A group of Canadian Forestry Service scientists (J. R. Blais, L. Archambault, D. A. MacLean, D. P. Ostaff, A. G. Raske, and W. L. Sippell) developed an indexing system to rate the vulnerability of forest management units in eastern Canada. The rating system is based on a combined volume of balsam fir and white spruce per hectare, the maturity of balsam fir, the combined volume of black and red spruce, and a climatic rating based on temperature and precipitation. From these parameters one can

Table 3—Estimated hazard and potential impact to balsam fir basal area (ft²/acre) in stands on mineral soils in Michigan's Upper Peninsula (Lynch et al. 1984b)

Region I: *Preoutbreak balsam fir basal area (ft²/acre)*

BA%AP	25	50	75	100	125
0	23	46	68	91	114
20	18	40	63	86	108
40	12	35	58	80	103
60	7	30	53	75	98
80	2	25	47	70	93
95	0	21	43	66	89

Region II: DBA.BF = 4±5 ft²/acre

Region III: Stands with less than 44 ft²/acre of balsam fir basal area
DBA.BF = 6±7 ft²/acre

□ = Low hazard.
□ = Moderate hazard.
■ = High hazard.

Table 3—cont'd

Region III: Stands with greater than 44 ft^2/acre of balsam fir basal area

Stand component 50 percent balsam fir, by number of stems

Range	*Preoutbreak balsam fir basal area (ft^2/acre)* 50	75	100	125
28	12	21	30	39
32	16	25	34	43
36	21	30	39	48
40	25	34	43	52
44	30	39	48	57

Stand component 70 percent balsam fir, by number of stems

Range	*Preoutbreak balsam fir basal area (ft^2/acre)* 50	75	100	125
28	0	5	14	23
32	1	10	18	27
36	5	14	23	32
40	10	19	28	36
44	14	23	32	41

Stand component 90 percent balsam fir, by number of stems

Range	*Preoutbreak balsam fir basal area (ft^2/acre)* 50	75	100	125
28	0	0	0	7
32	0	0	3	12
36	0	0	7	16
40	0	3	12	21
44	0	7	16	25

☐ = Low hazard.
☐ = Moderate hazard.
■ = High hazard.

calculate a numerical vulnerability index, and this computed index can be ranked by class.

Use table 4 to determine the vulnerability of stands in eastern Canada:

1. Determine the combined volume of balsam fir and white spruce and assign a rating value.
2. Determine the percentage of the balsam fir trees more than 60 years old and assign a rating value.
3. Determine the combined volume of black and red spruce (use the same rating scale as for step 1).
4. Rate climate from warm–dry to cool–wet. If part of the management unit occurs in a particular climatic rating while the remainder is in another rating, compute a weighted average.
5. Compute the vulnerability index (VI) as:

$$VI = (Vr1 * Mr) + Vr2 + Cr$$

where

$Vr1$ = balsam fir–white spruce volume rating,

Mr = balsam fir maturity rating,

$Vr2$ = black–red spruce volume rating. ($Vr2$ is 0 if $Vr1$ is ≤ 4.)

Cr = climate rating.

Vulnerability classes range from low to very high. Blais and Archambault (1982) computed and mapped vulnerability indexes for forest management units in Quebec from the most current inventory data. MacLean (1982) did the same for two sizes of inventory units in New Brunswick and two in Nova Scotia. Inventory data are being analyzed for Newfoundland.

Table 4—Index used to rate fir vulnerability to spruce budworm attack in New Brunswick and Nova Scotia (from MacLean 1982; Blais and Archambault 1982)

Combined volumes of balsam fir and white spruce

Volumes of fir and spruce (m^3/ha)	*Rating*
1–6	1
7–13	2
14–20	3
21–27	4
28–34	5
35–41	6
42–48	7
49–55	8
56–62	9
63 +	10

Rating for balsam fir maturity

Percent fir over 60 yr old	*Rating*
1–20	1
21–40	2
41 +	3

Table 4—cont'd

Combined volumes of black and red spruce[1] (same numerical scale as for fir and spruce)

Rating for climate		Vulnerability	
Climate	*Rating*	*Vulnerability index*	*Vulnerability class*
warm–dry	8	0–7	Low
warm–wet	4	8–15	Moderate
cool–dry	4	16–24	High
cool–wet	0	25 +	Very high

warm = mean annual temperature of 36.5 °F (2.5 °C) or more
cool = mean annual temperature below 36.5 °F
dry = precipitation of 35.4 inches (900 mm)/yr or less
wet = more than 35.4 inches/yr

[1]This rating is zero if volume rating for balsam fir and white spruce (Vrl) is 4 or less.

Final Discussion

Five rating systems have been developed to assist land managers in predicting spruce budworm damage in spruce–fir stands in eastern North America. The rating systems are easily implemented because the necessary data are readily available from routine compartmental examinations and inventory systems, or from budworm population and damage assessment surveys. Three of the rating systems (Batzer and Hastings 1980, Lynch and Witter 1984b, Olson et al. 1982) have been presented in formats that can be easily used by forest managers when conducting routine compartmental examinations. The other two rating systems are primarily used by forest pest management specialists as a tool in making regionwide planning decisions.

Forest-management decisions should be based on relative, rather than absolute estimates of impact. Stands should be indexed or ranked according to estimated losses. The relative ranking is one decision criteria or component of the entire stand-management program. Rating systems provide forest managers and pest managers with useful management tools and assist the managers in making decisions. Pest management is one aspect of forest management, and rating systems are one tool available in pest management programs.

Acknowledgments

We thank the following for their reviews of the manuscript: Louis Archambault, Canadian Forestry Service, Sainte-Foy, PQ; Robert Ford, USDA Forest Service, St. Paul, MN; Charles Hatch and Daniel Kucera, USDA Forest Service, Broomall, PA; Robert Heyd, Michigan Department of Natural Resources, Marquette; and David MacLean, Canadian Forestry Service, Fredericton, NB. We also thank Charles Olson Jr., Gary Fowler, and Bruce Montgomery, The University of Michigan, for important contributions to the draft.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1985 - 457-394 - 814/21109